Development of realistic models of oil well by modeling porosity using modified ANFIS technique

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***Abstract* — This paper present with the development of realistic models for predicting porosity by applying machine learning concepts on petro-physical logs. This paper is motivated due to increased exploration of unconventional hydrocarbon resources. Hence development of realistic models will reduce the exploration costs. Oil well data is modeled using modified ANFIS, consisting of optimized membership functions and fine tuned FIS model. The modified ANFIS model was constructed and tested on data samples recorded from niger delta basin. The average root mean square deviation is calculated. The results reported in this paper indicate that proposed oil well neutron porosity model can lead to the construction of more reliable static reservoir models for oil well simulation frameworks.**

Keywords — Oil Well Simulation, Modeling, Machine Learning, Porosity, Neural Networks, Fuzzy Logic, ANFIS.

I. INTRODUCTION

The recent developments in artificial intelligence and soft computing techniques have opened new avenues for researchers to explore prediction of application parameters. These machine learning techniques consist of several intelligent computing paradigms, including artificial neural networks, support vector machine, genetic algorithm, fuzzy decision tree, adaptive neuro-fuzzy systems, which have been successfully used to model various real world problems [1]. Application areas broadly range from medical, engineering, geophysics, gaming, finance, share markets and biotechnology etc.

Oil well simulation frameworks uses different categories of data like well log data, core analysis data, sesimic amplitude data, acoustic impedance data. All this data are correlated to rock and fluid properties. Fluid flow in porous medium is understood as the flow of liquid or gas or both in a medium filled with small solid grains. With the increasing exploration and development of unconventional hydrocarbon resources, the estimation of petrophysical parameters from well logs and oil well simulations is gaining importance. That is because those parameters from well logs in conjunction with core analysis can help geo-scientists understand the characteristics and properties of unconventional resources. Petro-physical parameters used in oil well simulation are total organic ,carbon content, mineral components, porosity and hydrocarbon saturation.

Porosity is a measure of how much of rock is open space. Porosity(φ) used in petroleum reservoirs usually have heterogeneous porosity distribution. A reservoir is homogeneous if porosity is constant independent of location. Mathematical formula for porosity is φ = interconnected pore volume / bulk volume. Permeability is a measure of the ease with which a fluid can move through a porous rock.

Jyh-Shing, Roger Jang in their paper “ANFIS: Adaptive-Network-Based Fuzzy Inference System” presented the architecture and learning procedure underlying ANFIS, a fuzzy inference system implemented in the framework of adaptive networks [2]. Briefly, ANNs are designed based on simulation of the human brain with the purpose of determining the relationship between outputs and inputs of a system. An ANN is trained with the available experimental data throughout the training step and is employed for estimating the unknown data. Neural networks include, simple synchronous processing components that are known as nodes or neurons located throughout layers. Usually, an artificial neural network has three layers: an output layer, a hidden layer, and an input layer.

An adaptive neuro-fuzzy inference system (ANFIS) is a kind of artificial neural network that is based on Takagi–Sugeno fuzzy inference system. It integrates both neural networks and fuzzy logic principles and captures the benefits of both in a single framework [2][3]. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be a universal estimator.

ANFIS with proper number of rules is able to model every plant. Therefore, ANFIS systems are widely used and play the advantage of good applicability since they can be interpreted as non-linear modeling and conventional linear techniques for state estimation and control [4].

The most common type of artificial neural networks (ANN) in oil well simulation applications is multi-layer perceptron (MLP) which is trained with aim of a back propagation (BP) approach [5].

In this paper, heterogeneous oil well porosity parameter is modeled using the transit time and bulk density. membership function and fine tuned fuzzy rules is developed analyzing the error output and iterations.

Section I, contains the introduction of simulation of oil well parameters, different modeling techniques and development of non linear model using ANFIS. Section II contain the related work of oil well modeling, Section III contain the methodology of modeling. Section IV contain the results and analysis of the results. Section V concludes the research and provides next steps.

II. Related Work

Akbar E, Sina A, et.al in their paper, "Oil Reservoir Permeability estimation from well logging data using statistical methods", indicate that sonic log, density log, neutron log and resistivity log have most effect on permeability [6].

O.I.Horsfall, E.D.Uko et.al in their paper "Comparative analysis of sonic and neutron-density logs for porosity determination" have done statistical analysis and concluded that neutron-density logs are more reliable than sonic density logs for porosity data estimation [7].

Baouche R, Baddari K in their paper, "Prediction of permeability ad porosity from well log data using the nonparametric regression with multivariate analysis and neural network, Hassi R'Mel Field, Algeria" implemented model based cluster analysis using alternating conditional expectations (ACE), generalized additive model and neural networks [8]. In this paper, it is concluded that data classification based on electrofacies characterization is more robust compared to other approaches.

III. Methodology

The sonic tool measures the time it takes sound pulses to travel through the formation (□t_{log}). The sonic or acoustic log measures the travel time of an elastic wave through the formation. This information can also be used to derive the velocity of elastic waves through the formation.

The density log measures the bulk density of the oil well reservoir and associated rocks. The density tool or gamma density tool utilizes a gamma ray source placed a distance from the gamma ray detector, which measures gamma ray count that is an inverse function of the density of the oil well.

Both this parameters are given as inputs to the oil well neutron porosity ANFIS model. ANFIS is a kind of artificial neural network that is based on Takagi–Sugeno fuzzy inference system. It integrates both neural networks and fuzzy logic principles and captures the benefits of both in a single framework. ANFIS is considered to be a universal estimator.

Oil well porosity ANFIS model consists of a set of fuzzy IF-THEN rules that have learning capability to approximate nonlinear functions. ANN is a model which processes information based on the structure and functions inspired from human brain.

ANN Supervised learning model with various algorithms backpropagation, hybrid algorithms are explored to develop optimal oil well porosity model. In the oil well modeling system the fuzzy logic takes the inaccuracy and uncertainty of the system which is being modeled, while a neural network provides a sense of adaptability. First step in modeling of this hybrid method requires developing initial fuzzy model along with its input variables. This is processed with the help of the rules extracted from the input output data of the system that is being modeled. In order to produce the final ANFIS model of the system, the neural network is used to fine tune the rules of the initial fuzzy model.

Its membership function parameters are adjusted by using a back propagation algorithm in combination with a least squares method. This tuning of the parameters allows the fuzzy systems to learn from the data that is being modeled.

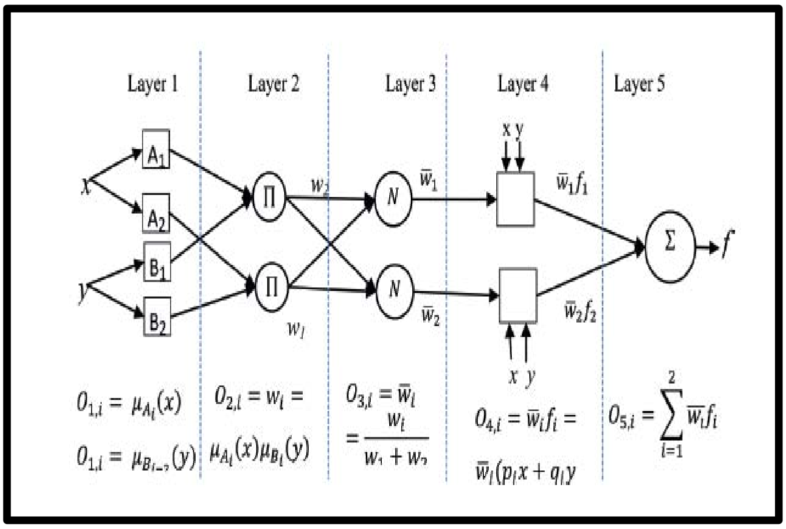

Figure 1. ANFIS five layer architecture

ANFIS Architecture used for oil porosity model consists of 5 layers. In Layer 1 degree of the membership function is identified. Output of the layer2 is the product of the incoming signals. Layer 3, Each node normalizes the strength of the rule. Layer 4 does the Defuzzification using consequent parameters. Layer 5 converts the fuzzy result to crisp output. A network-type structure maps inputs through input membership functions. Outputs through output membership functions. The parameters associated with the membership function changes through the learning process. The computation of these parameters is facilitated by a gradient vector.

This gradient vector provides a measure of how well the fuzzy inference system is modeling the input/output data for a given set of parameters. When the gradient vector is obtained, optimization routines are applied in order to adjust the parameters to reduce error measure.

This error measure is defined by the sum of the squared difference between actual and desired outputs. Oil well ANFIS porosity model uses back propagation in combination of least squares estimation and back propagation for membership function parameter estimation.

If the training data presented to ANFIS from FIS for estimating membership function parameters fully represents the features of the data, this type of modeling works well. But the training data cannot be representative of all the features of the oil well as the data is collected using noisy measurements. Model validation becomes helpful and is used in verifying the oil well porosity model. Model validation is the process by which the input vectors from input/output data sets on which the FIS was not trained, are presented to the trained oil well porosity FIS model, to see how well the FIS model predicts the corresponding data set output values.

FIS model generated is inputted to ANFIS network using hybrid and back propagation techniques. Number of membership functions is fine tuned based on the variance of the input data. Well-1 data contained Transit Time, Bulk density logs taken at interval of 10 meters for oil well depth ranging from 1200 to 1500. Well-2 data contained Transit Time, Bulk density logs taken at interval of 10 meters for oil well depth ranging from 1150 to 1450 meters.

IV. RESULTS AND DISCUSSION

Oil well data from niger delta basin is used in the development of porosity model using ANFIS. FIS model was developed using sugeno fuzzy inference system. Different membership functions for the fuzzy rules is explored on the input data.

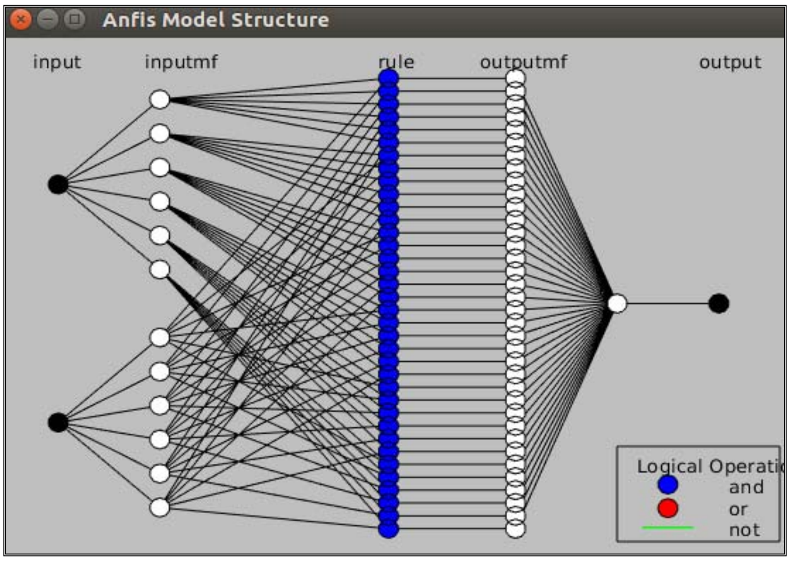

Figure 2. ANFIS model for estimating porosity using two inputs

Figure 2 shows the oil well porosity ANFIS model interlinking input and output parameters using FIS rules.

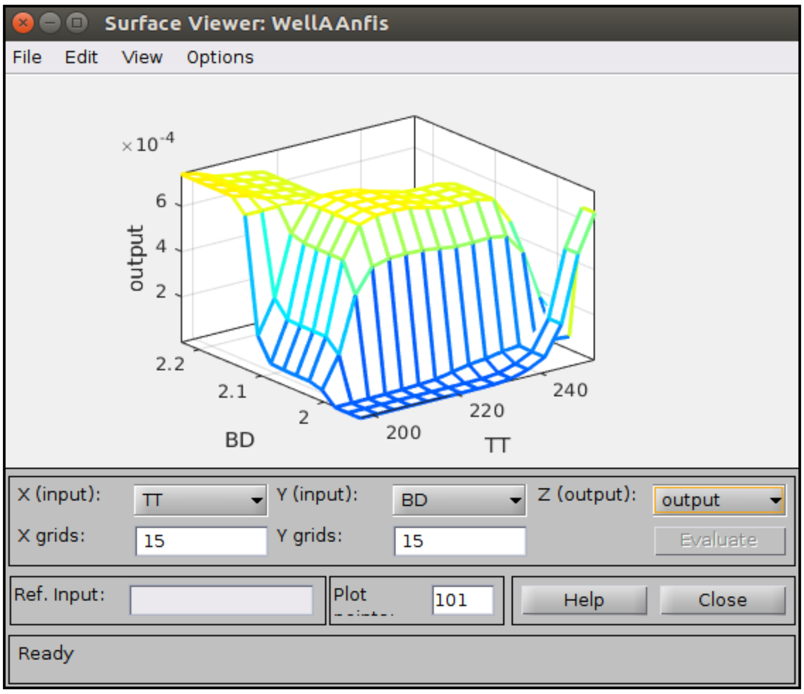

Figure 3. Surface viewer of porosity neutron ANFIS model

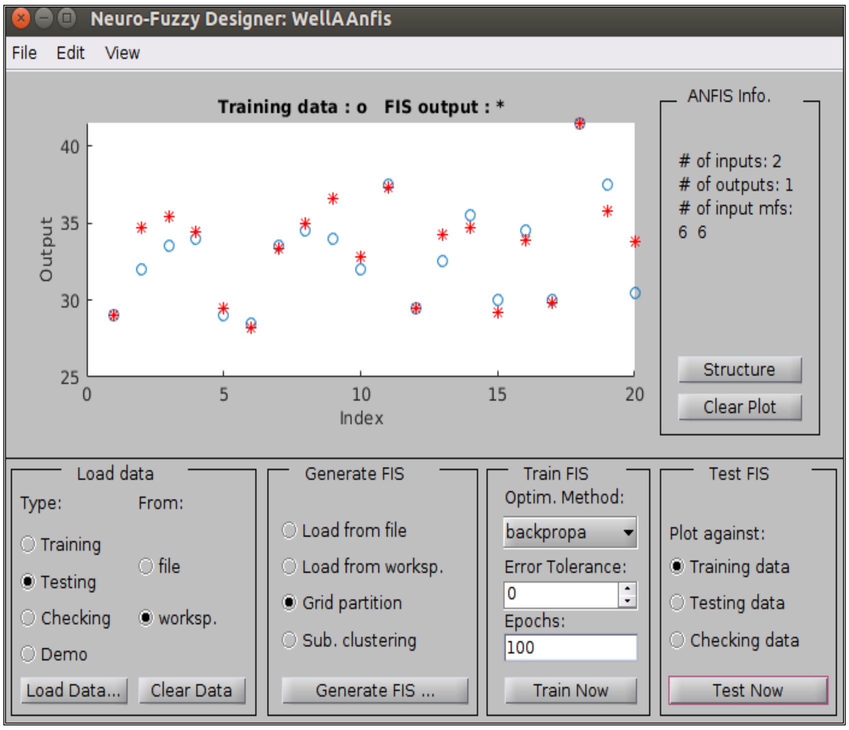

Figure 4. Estimated porosity from ANFIS model vs Actual porosity data of oil well-1on Training set.

Table 1. Average error comparison of neutron porosity ANFIS model

ANFIS Results	Average Error of Neutron Porosity Model		
	Well	***Gaussian Membership Function***	***Triangle Membership Function***
1	Well-1	1.5417	3.476
2	Well-2	2.2346	5.7845

Table-1 gives the comparison of validation error for different membership functions.

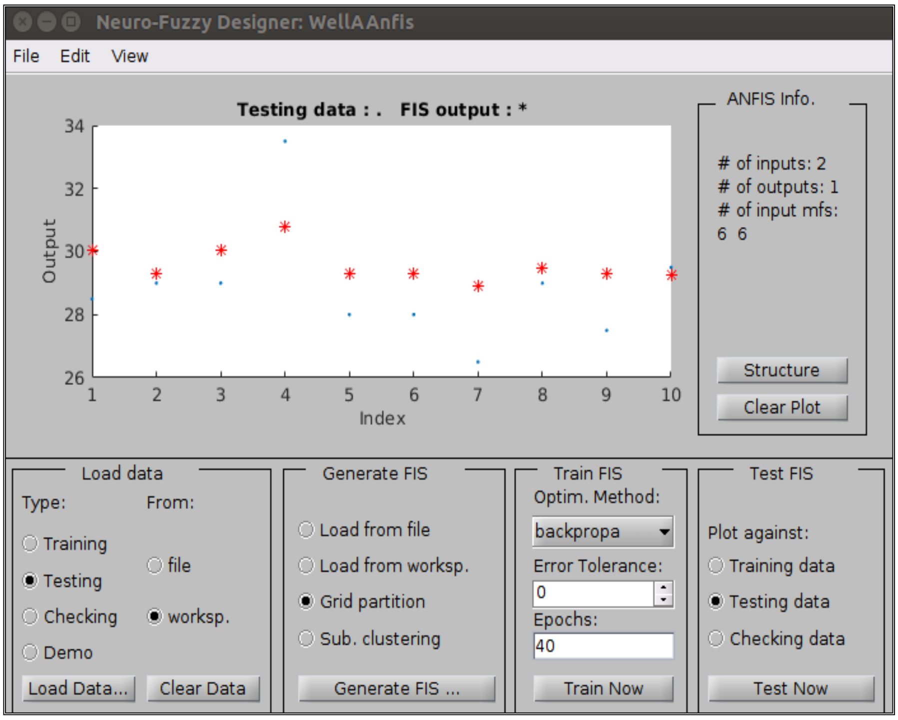

Figure 5. Estimated porosity from ANFIS model vs Actual porosity data of oil well-1 on test set

V. CONCLUSION AND FUTURE SCOPE

This paper presents modelling of heterogenous oil well neutron based porosity at different depths using ANFIS model. Gaussian membership function with optimal selection of rules and fine tuned FIS object will gives accurate model. Among the hybrid and backpropagation techniques, backpropagation provided better results as the average error on the validated data is less compared to hybrid method. Future work can be done on estimating permeability with additional petro physical log parameters.

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